IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES PROVISIONAL PATENT APPLICATION

for

IMPROVED WIRELESS COMMUNICATIONS SYSTEMS AND METHODS USING LONG-CODE MULTI-USER DETECTION

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Background of the Invention

The invention pertains to wireless communications and, more particularly, to methods and apparatus for interference cancellation in code-division multiple access communications. The invention has application, by way of non-limiting example, in improving the capacity of cellular phone base stations.

Code-division multiple access (CDMA) is used increasingly in wireless communications. It is a form of multiplexing communications, e.g., between cellular phones and base stations, based on distinct digital codes in the communication signals. This can be contrasted with other wireless protocols, such as frequency-division multiple access and time-division multiple access, in which multiplexing is based on the use of orthogonal frequency bands and orthogonal time-slots, respectively.

A limiting factor in CDMA communication and, particularly, in so-called direct sequence CDMA (DS-CDMA), is the interference between multiple simultaneous communications, e.g., multiple cellular phone users in the same geographic area using their phones at the same time. This is referred to as multiple access interference (MAI). It has effect of limiting the capacity of cellular phone base stations, since interference may exceed acceptable levels -- driving service quality below acceptable levels -- when there are too many users.

A technique known as multi-user detection (MUD) reduces multiple access interference and, as a consequence, increases base station capacity. MUD can reduce interference not only between multiple signals of like strength, but also that caused by users so close to the base station as to otherwise overpower signals from other users (the so-called near/far problem). MUD generally functions on the principle that signals from multiple simultaneous users can be jointly used to improve detection of the signal from any single user. Many forms of MUD are known; surveys are provided in Moshavi, "Multi-User Detection for DS-CDMA Systems," IEEE Communications Magazine (October, 1996) and Duel-Hallen et al, "Multiuser Detection for CDMA Systems," IEEE Personal Communications (April 1995). Though a promising solution to increasing the capacity of cellular phone base stations, MUD techniques are typically so computationally intensive as to limit practical application.

An object of this invention is to provide improved methods and apparatus for wireless communications. A related object is to provide such methods and apparatus for multi-user detection or interference cancellation in code-division multiple access communications.

A further object of the invention is to provide such methods and apparatus as can be cost-effectively implemented and as require minimal changes in existing wireless communications infrastructure.

A still further object of the invention is to provide methods and apparatus for executing multi-user detection and related algorithms in real-time.

A still further object of the invention is to provide such methods and apparatus as manage faults for high-availability.

Summary of the Invention

These and other objects are met by the invention which provides, in one aspect, a wireless communications system, referred to as the "MCW-1" (among other terms) in the materials that follow, and methods of operation thereof. An overview of that system is provided in the document entitled "Software Architecture of the MCW-1 MUD Board," immediately following this Summary. A more complete understanding of its implementation may be attained by reference to the other attached materials.

In view of those materials, aspects of the invention include, but are not limited to, the following:

- methods and apparatus for long-code multi-user detection (MUD) in a wireless communications system.

These and other aspects of the invention (including utilization of the aforementioned methods and aspects for other than wireless communications and/or interference cancellation) are evident in the materials that follow.

Detailed Description of the Invention

See the attached materials on pages 5 – 12 hereof, providing a block diagram of a preferred algorithm for long code MUD which includes identification of (roughly) how many GOPS are involved in each major function; a diagram showing interfaces between a long code MUD processing card according to the invention and a modem, e.g., of the type provided by Motorola (or another supplier of such components); and two block diagrams of the same BASELINE 0 board hardware architecture at a top level identifiying the processing nodes. The attached diagram entitled "Long-code Mapping to Hardware" illustrates support of 64 users for long code MUD and shows parts of the long code MUD algorithm supported by each processing node. The diagram entitled "Short-code Mapping to Hardware" illustrates support of 128 users for short code MUD and shows parts of the short code MUD algorithm would be supported by each processing node.

The aforementioned materials pertain to improvements on the methods and apparatus described in United States Provisional Application Serial No. 60/275,846, filed March 14, 2001, entitled IMPROVED WIRELESS COMMUNICATIONS SYSTEMS AND METHODS, the teachings of which are incorporated herein by reference and a copy of which is attached hereto. That copy bears the U.S. Postal Service Express Mail label number of both the original filing, as well as that of this filing (the latter being referred to as the "New Exp. Mail Label No.").

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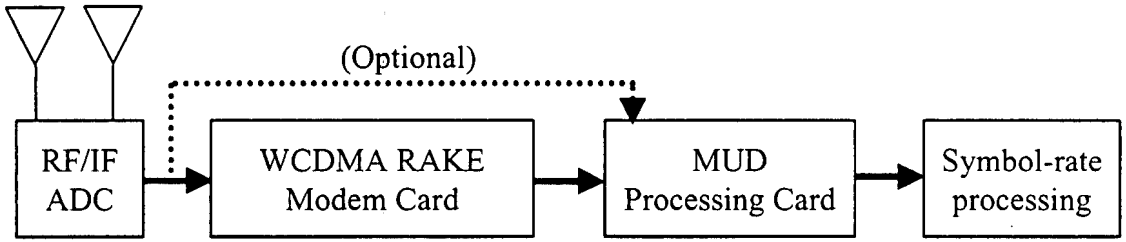
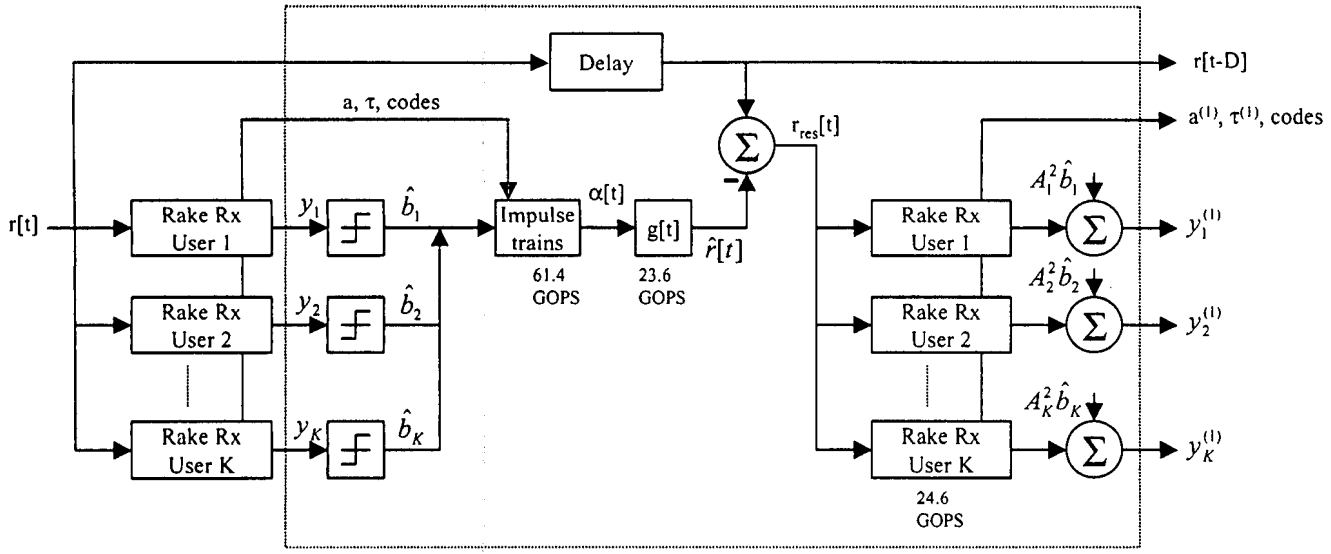
Long-Code Multiuser Detection Enhancement Concept



Optional antenna-stream input to MUD processing card allows multiple-stage interference cancellation and multiuser channel-amplitude estimation.

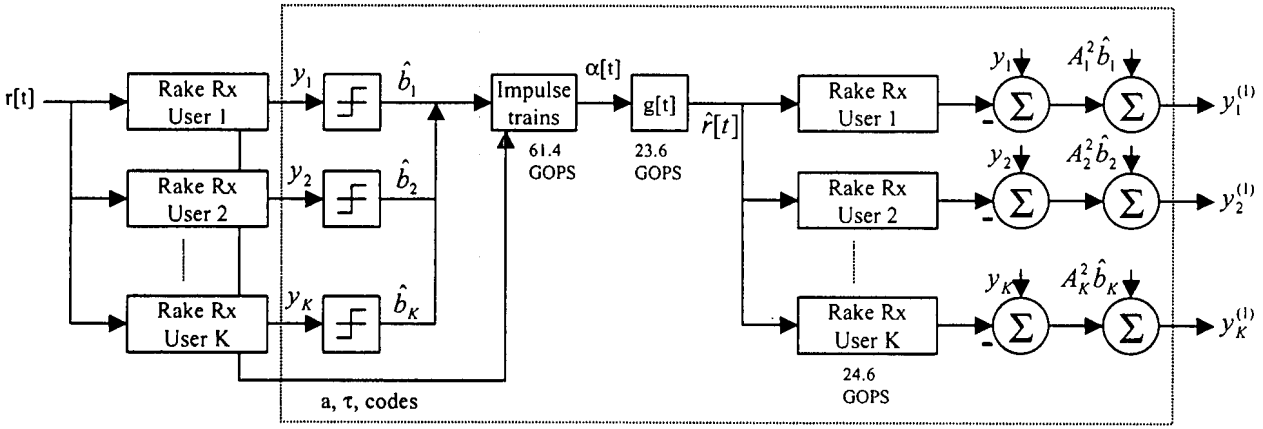
Block Diagram of Multiple-Stage Long-Code Algorithm



Computational complexity figures (GOPS) are based on

- 128 SF 256 users
- 4 multipath fingers
- 8 samples per chip

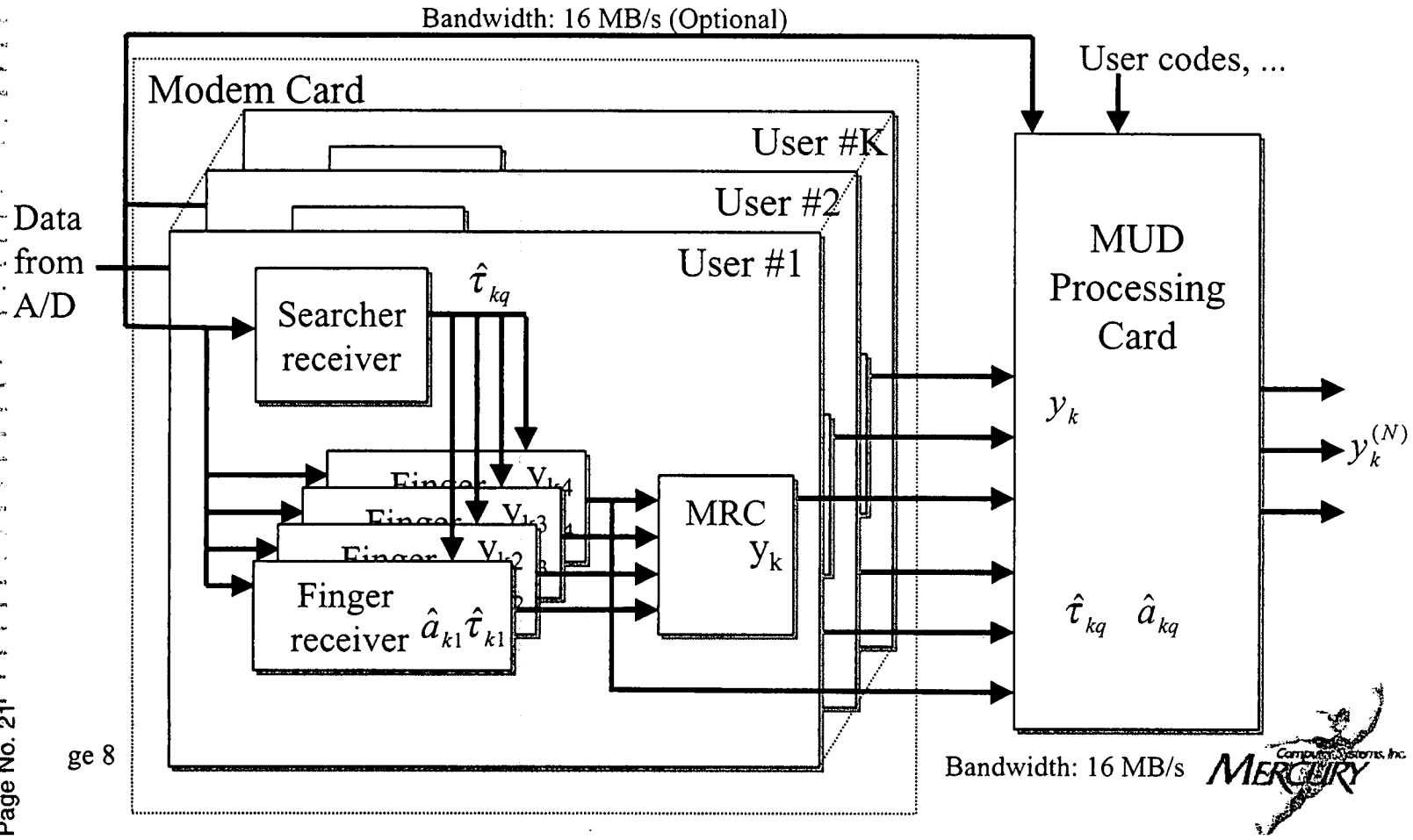
Block Diagram of Single-Stage Long-Code Algorithm



Computational complexity figures (GOPS) are based on

- 128 SF 256 users
- 4 multipath fingers
- 8 samples per chip

MUD Interface to Modem



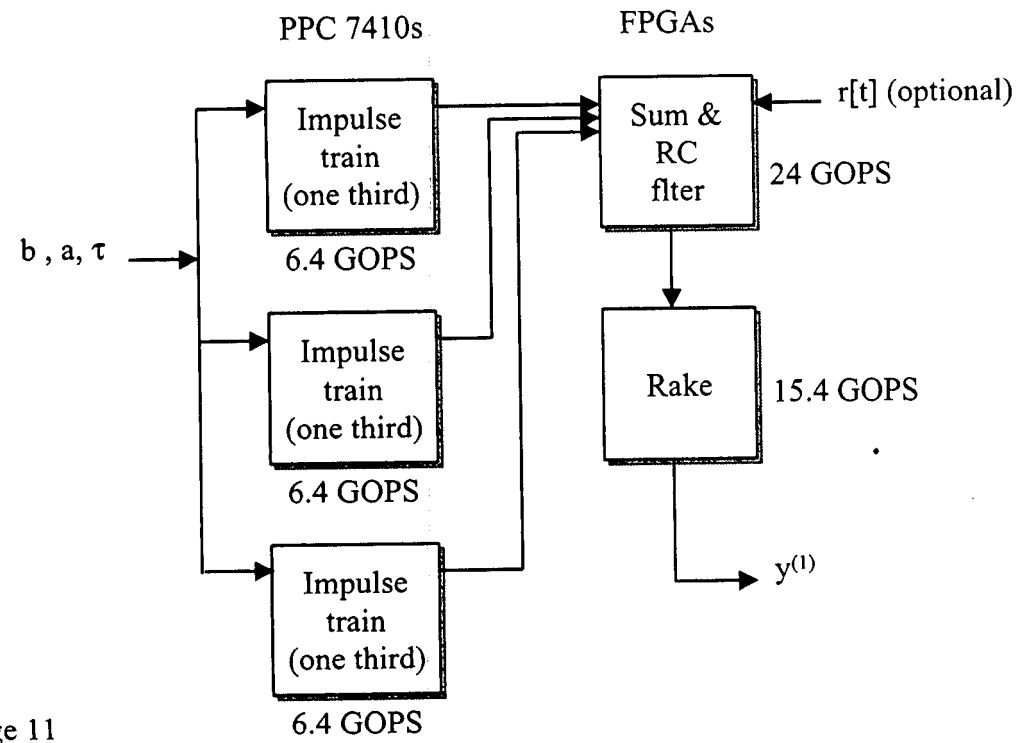
Data Transferred to or from MUD Processing Card

- Inputs
  - Frame number
  - Post-MRC matched-filter outputs y_k for DPCCH and DPDCHs
  - Number of DPDCHs
  - DPCCH slot format
  - Number of rake fingers
  - Number of antennas used
  - Channel amplitude estimates a_{kq}
  - Channel lag estimates τ_{kq}
  - Spreading factor SF_k
  - Code number
  - Compressed mode information
    - Compressed mode flag, Compressed mode frame, N_first, TGL
  - Amplitude ratios β_{dk}, β_{ck}
  - Antenna streams *r[t]* (Optional)
- Outputs
  - Cleaned data bit estimates b_k

Long-code MUD Processing Card Interface Bandwidth

Data Description	BW (MB/s)
Antenna streams	16.00
Post-MRC outputs y_k	3.260
Channel amplitude estimates a_{kq}	6.144
Channel lag estimates τ_{kq}	0.001
Cleaned data bit estimates b_k	1.920
TOTAL	27.325

Long-code Mapping to Hardware



Short-code Mapping to Hardware